

## SOIL EROSION OVER DIFFERENT SLOPES UNDER PINE STANDS

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SOIL EROSION OVER DIFFERENT SLOPES UNDER PINE STANDS. Forests have an important role in controlling soil erosion. Pine stands are considered effective in controlling erosion due to high interception and thick litter. This study compares the level of erosion on land with a slope > 40% to land with a slope <40%, as one of the references used in reviewing standards for determining the slope of a protected forest area. The study was conducted from November 2016 to February 2017, under *Pinus merkusii* stand in the Education Forest of Hasanuddin University in Maros Regency. Erosion was measured in a land of 22 m x 4 m having long slopes > 40% and < 40% with 3 replicates. Surface runoff was measured during rain and suspension levels was determined based on a dry oven heated at 105°C. Actual erosion (gr) is calculated by multiplying total runoff volume (m<sup>3</sup>/plot) by suspension level (gr/m<sup>3</sup>). The results show the average erosion on the slopes >40% was 54.94 g/plot or 0.006 tons/ha while on the slopes <40% was 36.74 g/plot or 0.004 tons/ha. The average difference of the two test results, with a 95% confidence interval, shows differences in the erosion average on the slopes > 40% and <40%. However, when there is an increase in the percentage of canopy cover the erosion becomes smaller even on the slopes > 40%. This research can be used as a reference for considering the increase in the upper limit of the slope of the protected forest area, and the need for further evaluation on the existing upper limit value.

Keywords: Erosion, rainintensity, slope, pine stands, closure

*EROSI TANAH PADA BERBAGI LERENG DI BAWAH TEGAKAN PINUS. Hutan memiliki peran penting dalam mengendalikan erosi tanah. Tegakan pinus dianggap efektif mengendalikan erosi karena intersepsinya yang tinggi serta serasah yang tebal. Penelitian ini bertujuan untuk membandingkan tingkat erosi antara kemiringan lereng >40% dengan lereng <40%, sebagai rujukan dalam tinjauan ulang standar penetapan Kawasan hutan lindung berdasarkan keterlereng >40%. Penelitian dilakukan mulai bulan Nopember 2016 sampai Februari 2017 di bawah tegakan Pinus merkusii Hutan Pendidikan Universitas Hasanuddin di Kabupaten Maros. Pengukuran erosi dilakukan dalam plot lahan berukuran 22 m x 4 m pada lereng >40% dan <40% masing-masing 3 ulangan. Pengukuran limpasan permukaan dilakukan setiap kejadian hujan, sebanyak 39 kali hujan. Kadar suspense diperoleh dengan cara mengeringkan air limpasan dalam oven suhu 105°C. Erosi aktual (gr) dihitung dengan mengalikan total volume limpasan (m<sup>3</sup>/plot) dengan kadar suspensi (gr/m<sup>3</sup>). Hasil penelitian menunjukkan rata-rata erosi pada lereng >40% 54,94 g/plot atau 0,006 ton/ha dan 36,74 g/plot atau 0,004 ton/ha pada lereng <40%. Hasil uji beda 2 rata-rata dengan selang kepercayaan 95%, menunjukkan perbedaan rata-rata erosi pada lereng >40% dan <40%. Namun ketika terjadi peningkatan persentase penutupan tajuk, erosi menjadi lebih kecil meskipun pada lereng 40%. Penelitian ini merekomendasikan peningkatan batas atas kemiringan kawasan hutan lindung dan perlunya peninjauan kembali atas nilai batas atas yang berlaku saat ini.*

*Kata kunci: Erosi, intensitas hujan, lereng, tegakan pinus, penutupan*

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## I. INTRODUCTION

Indonesia is included in the three countries after Brazil and the Democratic Republic of Congo with a high level of primary forest destruction (Weisse & Goldman, 2020). This damage reduces the ability of forests to carry out their ecological functions. The interaction of the forest with its environment begins to be disturbed so that floods, erosion, landslides are inevitable. Forest stands have an important role in controlling erosion (Razafindrabe, He, Inoue, Ezaki, & Shaw, 2010). The dense canopy can reduce the kinetic energy of rain falling to the ground. Forest cover can affect infiltration (Gupita & Murti, 2017), and increase soil resistance to raindrop damage. Dense vegetation can control the rate of erosion even on slopes and high rainfall. Erosion gets smaller with increasing vegetation density (Jianbo L et al., 2018)

Maintaining and or rebuilding forests, especially on lands with high slope, are the answer to controlling the rate of erosion, where erosion causes a decrease in land quality. In this regard, various efforts have been carried out to rebuild forests, including through planting programs known as reforestation, planting a million trees, Reforestation Week and the National Movement for Forest and Land Rehabilitation. Specifically in South Sulawesi, a large-scale reforestation program, in the context of overcoming critical lands in forest areas, has been promoted since the early 70s. The most widely used species is *Pinus merkusii*.

The reality on the ground shows that the rate of increase in critical land is faster than the success rate of forest rebuilding, due to the high level of land demand for various purposes. Fulfilment of land requirements is intended to make forest areas the main target, including protected forest areas. In many cases, the fulfilment of these no longer needs to consider the carrying capacity of the forest land, whether that is done legally or illegally.

According to the Law No. 41 of 1999 concerning Forestry article 6 (2), the government determines forests based on the main functions

of conservation, protection, and production. While Article 19 paragraph (1) of the Law states that the government determines changes to the designation and function of forest areas based on integrated research results.

Zulkarnain and Widayati (2013) stated that the determination of forest areas with slope, soil type and rainfall criteria could not be used as a basis for criteria in determining protected forest areas. The main criteria that can be used in determining forest areas is calculating the community of trees as forest formers. The community factor of the trees is not sufficient to be used as a reference for establishing protected areas, it still needs to consider the slope aspect. Therefore, the slope standard from 40% needs to be reviewed. Facts on the ground show many parts of the forest with a slope above 40% are also exploited and converted. This invites a fundamental question of whether this 40% number will remain a basic reference to develop all parts of the forest area with the main function as protected forest areas or should it be realistic to say that the figure limit should be reviewed to determine further the boundary that is more likely to be applied in the field.

Answering this question requires data and information support, in this case, data that can prove the difference in the level of erosion on slopes above 40% with those below 40%. Data and information are influenced not only by slope inclination, but also by the closure. Therefore further information is needed about the significance of the difference in the level of erosion in the two slope categories with vegetation cover type.

One species of forest cover that should be considered for this purpose is *Pinus merkusii*. Based on consideration since the early 70s, this species has been widely used for reforestation planting. Based on existing records, this species has been used as a reforestation trees since the Dutch colonial administration era, especially in Java. This species has the potential to control erosion and landslides because it has a high interception (Rosmaeni et al., 2019), deep roots,

high evapotranspiration, binding the soil, and the trees are not too heavy or light (Lan H et al., 2020).

Research of Topic et al. (2008) found that the soil loss in the black pine (*Pinus nigra* Arn.) stand with a thick layer of natural litter and grass with a slope of 32° (62.49%) was 0.0116 ton/ha. In the black pine stand with complete canopy and no grass, the soil loss is 0.0204 ton/ha. In the stand of *Pinus aleppo* (*Pinus halepensis* Mill.) with complete cover at a slope of 20° (36.4%), the soil loss was 0.044 ton/ha.

This paper studies the role of pine plantations to reduce erosion rates. Specific research is needed to compare erosion rates on land with slope classes > 40% and on the slope classes <40%. It is considerable that land, which according to applicable regulations, should be managed as a protected area.

## II. MATERIAL AND METHOD

### A. Location and Materials

This research was carried out for four months from November 2016 to February 2017. The research was conducted under a stand of pine (*Pinus merkusii*) forests located in the Educational Forest of Hasanuddin University, Maros Regency, South Sulawesi Province. The study site is located at an altitude of 300-800 m above sea level. The average annual rainfall based on records from 2007 to 2016 was 2,863.2 mm.

The pine forest has been planted since 1970 as a result of reforestation covering an area of 291.13 ha. This stand is generally found in the northern part that spreads on lands with topographic conditions that vary from bumpy to steep.

Stand density on slope plots >40% and <40% were the same, i.e. 11 trees per 400m<sup>2</sup>, consisting of four classes, namely trees, poles, saplings and seedlings. On slope plots >40% there are 11 trees, 2 poles, 2 saplings, and 3 seedlings. There are 11 pine trees and 2 other species. The average pine diameter is 49.36 cm. While on the slope plot <40% there are 11

trees, 7 poles, 7 saplings, 7 seedlings. There are 9 pine trees and 2 other species. The average pine diameter is 51.72 cm.

Tools and materials used in the field are observatory-type rainfall gauges, haga meters, roll meters, compasses, GPS, machetes, crowbars, hoes, rubber gutters for erosion test plots. Tools to collect runoff water from plastic buckets with capacities of 25 and 40 liters, bamboo for clamping rubber gutters, paralon pipes to drain runoff water into buckets, measuring cups, 600 ml plastic bottles, plastic caps for reservoirs, sample rings to take soil samples for analysis of organic matter, permeability and physical properties of the soil. Other tools are stationary, camera, stopwatch, label paper, and tally sheet. In this study, erosion plots using rubber gutters are cheaper and easier to install than using zinc and wooden boards. Some laboratory equipments used for sediments analysis included small funnels, measuring cups, filter paper for sediment solutions, digital scales, ovens, petri dishes, desiccators, and glitches.

### B. Methods

The erosion plot is placed under the pine stand. Each plot contained several pine trees, between 1 to 6 trees per plot. Apart from pine trees, both in and around the plot, there are also other species found in the plots, such as *Cinnamomum* Sp., *Sapindaceae* and *Alstonia scholaris* (total 1 to 2 trees). The trees around the plot partially cover the canopy of erosion plot. Stand density around the plot is 11 trees per 400 m<sup>2</sup> consisting of seedlings, saplings, poles and trees.

This research was conducted through direct measurements, including observations of rainfall per rainfall event, rain duration, rainfall intensity, the volume of surface runoff and dissolved suspensions, slope rates, undergrowth, litter thickness, canopy cover per plot, and soil physical properties. Rain intensity is classified into 4, e.i. light (1-5mm/hour), moderate (5-10mm/hour), heavy (10-20mm/hour) and very heavy (> 20mm/hour) (Meteorology and

Table 1. Percentage of canopy closure, number of trees and thickness of litter

Slope Class	Plot	Slopes (%)	Canopy Closure (%)	Number of Trees	Thickness of Litter (cm)
> 40%	1	58	68.66	5	3
	2	61	55.68	4	1.6
	3	72	71.2	5	3.3
< 40%	1	25	92.61	5	0.8
	2	27	71.02	4	2
	3	29	46.02	4	1.9

Geophysics Agency, 2017).

Table 1 shows percentage of canopy closure, number of trees and thickness of litter in the observation plots.

Rainfall data were obtained from rainfall measurement placed in an open space around the observation plot. Observations were made for each rain event with a total of 39 rain events. The test plots were placed on a slope of > 40% and <40% with a length of 22 m and a width of 4 m . This plot size was used to adapt to the slope length of the landscape and this has been applied as an international standard of the USLE (Universal Soil Loss Evaluation) plots to predict erosion and considered as the best measure for field research of erosion. The same plot length was also used by a study conducted by (Paimin, 2003). Plots are installed on slopes between 15-30% for slope classes <40%, slopes between 45-75% for slope classes > 40%. Each slope class was replicated 3 three times.

The plot is made of tarpaulin from rubber. The height of the tarpaulin side above the ground is 20 cm. On the outer side of the erosion plot, a small ditch is made as a barrier, so that runoff that occurs outside the plot does not flow into the erosion test plot. Each plot is described starting from the percentage of pine canopy cover, to litter thickness and slope level. Pine stand density consists of 3 categories: rare (10% -40%), moderate (41% -70%) and dense (> 70%) (Badan Standarisasi Nasional, 2010). While the slopes are also divided into four categories: hilly sloping (15-30%), rather steep (30-45%), steep (45-65%) and very steep (>

65%).

Runoff and sediment content reservoirs use three buckets with a capacity of 50 litres. The magnitude of the actual erosion that occurs every time a rain event is known through sediment analysis. The method of taking samples is by stirring runoff water accommodated in a bucket until the sediment is evenly mixed. Then the sample is put into a 600 ml plastic bottle. The erosion plot can be seen in Figure 1.

**C. Analysis**

Primary data in the form of sediment concentration 20 ml is taken from each sample and then filtered using filter paper until the water runs out. Then it is dried at 105°C until the weight of dry soil is obtained. The dried samples were then weighed.

The formulas used to calculate sediment concentrations are:.....(1)

$$C = \frac{(b-a)}{v}$$

where:

C = Sediment concentration (g/m<sup>3</sup>)

b = Weight of filter paper containing erosion (g)

v = Volume of erosion sample (m<sup>3</sup>)

The amount of actual erosion can be calculated by multiplying the total runoff volume (m<sup>3</sup>) by the level of suspension (g/m<sup>3</sup>),

$$\text{Actual Erosion (g)} = \text{Total runoff volume (m}^3\text{)} \times \text{Sediment concentration (g/m}^3\text{)} \dots\dots(2)$$

which can be written as follows:

Linear regression analysis was performed to determine the relationship between the factors that influence erosion. Diversity

analysis (ANOVA) was conducted to determine which variables were different by comparing the average value of erosion based on the Independent Samples T-Test.

### III. RESULT AND DISCUSSION

#### A. Result

Results of erosion regression analysis with independent variables (rainfall intensity, closure and slope) are shown in Table 2.

As shown in Table 2, the regression analysis results show that rainfall intensity, closure, and

slope together have a significant statistical relationship to erosion, that is shown by the value of significance level below 0,05 (Sig 0.000b).

Furthermore, in Table 3 it can be shown the relationship of each independent variable with erosion.

As shown in Table 3, the regression analysis results show that rainfall intensity and closure have a significant relationship with erosion. While other variables, namely the contribution of the slope to the effect of intensity (Z. Intensity) and the contribution of the slope

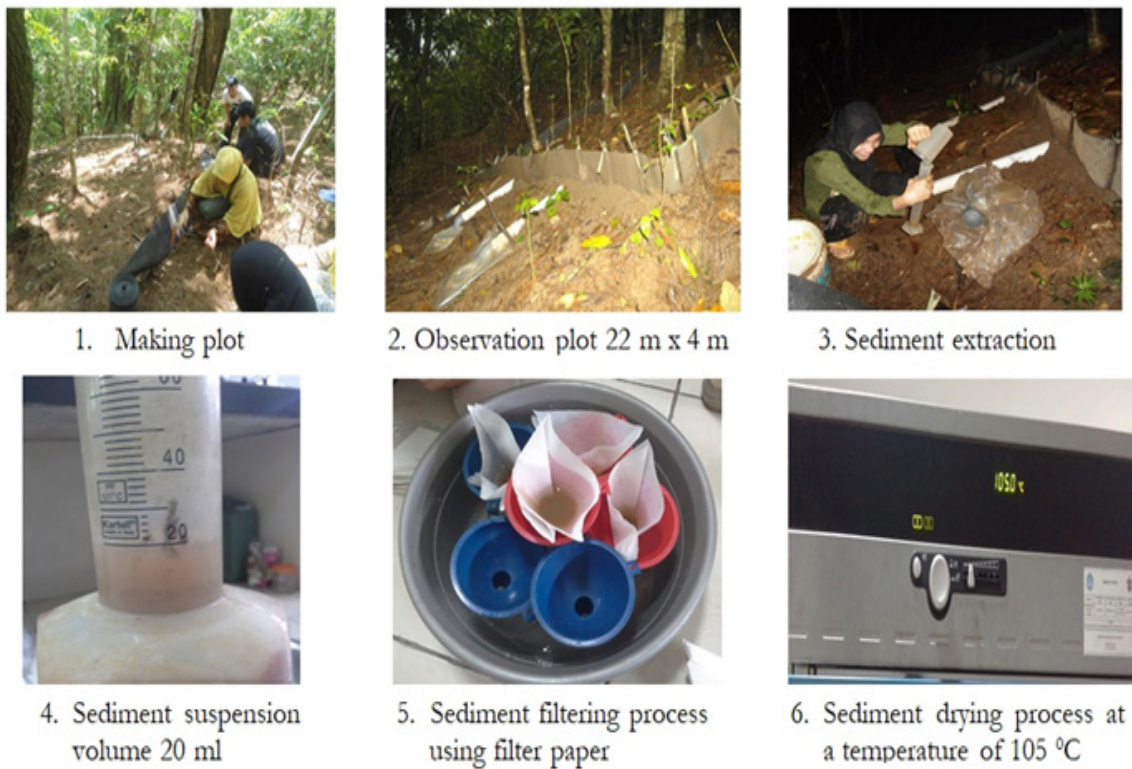


Figure 1 Erosion plot

Table 2. Regression analysis of the relationship between erosion and intensity, closure and slope

ANOVA <sup>a*</sup>					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	144335.62	4	36083.91	9.808	0.000 <sup>b</sup>
Residual	842540.29	229	3679.22		
Total	986875.91	233			

Remarks: a\*. Dependent Variable: erosion

b. Predictors: (Constant), closure, intensity

Table 3. Regression analysis of the relationship between erosion and rainfall intensity, closure, Z. intensity, Z. closure on slopes below 40% and above 40%

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
1 (Constant)	49.42	21.60		2.287	0.023
Rainfall intensity	17.53	7.29	0.208	2.405	0.017
Closure	-25.22	6.87	-0.224	-3.672	0.000
Z.Intensity	10.87	10.31	0.202	1.054	0.293
Z.Closure	-3.03	11.79	-0.047	-0.257	0.797

Note: a. Dependent Variable: erosion

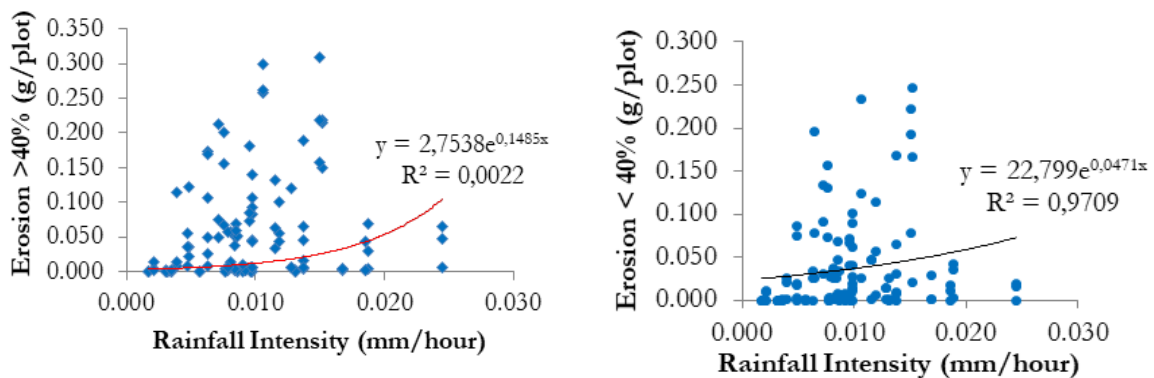


Figure 2 Graphic relationship between rainfall intensity and erosion on slopes > 40% and <40%

to the effect of closure (Z. Closure), do not have a significant relationship with erosion. The effect of rainfall intensity is positive 17.53. This means that each increase in one unit of intensity will increase surface erosion by 17.53 g/plot, assuming other variables are of a fixed value. The closure coefficient value of the negative variable is 25.22, meaning that each increase of one unit of closure will reduce the surface erosion by 25.22 g/plot, assuming the other variables are of a fixed value.

Based on the regression test, closure is significantly associated with erosion at slopes below 40% and above 40%. The independent variable Z.intensity is not evident on slopes above 40%, meaning that the slope does not contribute to the effect of intensity on erosion. Therefore it can be explained that the effect of

intensity and slope on erosion can be eliminated by the presence of dense closure both on slopes below 40% and above 40% (E1-Hassanin et al., 1993) ; (Ispriyanto et al., 2001).

The relationship of rainfall intensity with erosion on slopes > 40% and <40% can be seen in Figure 2.

Figure 2 shows that rainfall intensity is positively correlated with erosion. The higher the intensity of rainfall, the greater the rate of soil loss. On slopes <40% the influence of rainfall intensity is greater, namely 97.59%. This shows that high rainfall intensity can cause high erosion even on low slopes (Cao et al., 2015)

Further tests of the relationship of intensity to erosion on slopes below 40% and above 40% can be seen in Figure 3.

Figure 3 shows that the average value of

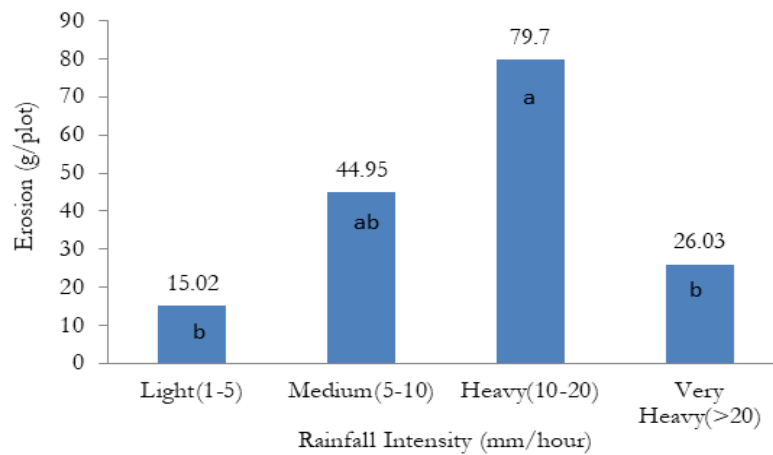


Figure 3. Graph of the Duncan test results in the relationship of rainfall intensity with erosion on slopes > 40% and <40%

Table 4. Duncan test results of closure relationship to erosion on slopes on slopes > 40% and <40%

% canopy closure	Erosion > 40%		% canopy closure	erosion < 40%		
	1	2		1	2	3
68.66%	33.46 <sup>c</sup>		92.61%	9.79 <sup>d</sup>		
71.20%	49.92 <sup>bc</sup>		71.02%		40.21 <sup>c</sup>	
55.68%		81.44 <sup>a</sup>	46.02 %			60.22 <sup>b</sup>

erosion at the intensity of heavy rainfall is 79.7 g/plot not significantly different from the moderate intensity of 44.95 g/plot, both are significantly different from the intensity of very heavy and light rain, respectively - each resulted in erosion of 26.03 g/plot and 15.02 g/plot. The erosion on very heavy rainfall intensity was lower than that on medium and heavy because the rain was short, 21 minutes and 24 minutes. The average erosion that occurred in all plots was smaller even though the intensity of the rain was very heavy at 24.5 mm/hour.

The relationship between cover and erosion on slopes below 40% and above 40% can be seen in Table 4.

Table 4 shows that on slopes > 40%, 55.68% closure results in erosion of 81.44 g/plot, significantly higher than 68.66% and 71.20% closure, with erosion rates of 33.46 g/plot respectively and 49.92 g/plot. While the three are significantly different on the slopes

<40%, 46.02% closure is significantly higher than 71.02% closure and significantly different at 92.61% closure. It produces erosion of 60.22 g/plot, 40.21 g/plot and 9.79 g/plot respectively. The higher the closure, the smaller the erosion will occur. Erosion will decrease with increasing plant cover (Luo et al., 2020).

Measurements were carried out for 4 months, starting at the beginning of the rainy season until the peak of the rain until the end of the rainy season, starting from November 2016 to February 2017, results shows that average soil erosion is 54.84 gr/plot or equal to 0.006 ton/ha.

The relationship between the slope and the amount of erosion can be seen in Figure 4.

Figure 4 shows that erosion at a slope of 61% and 27%, the resulting erosion is significantly different at a slope of 72%, 58%, 29%, 27% and 25%. There is no significant difference between erosion generated at a slope of 25%,

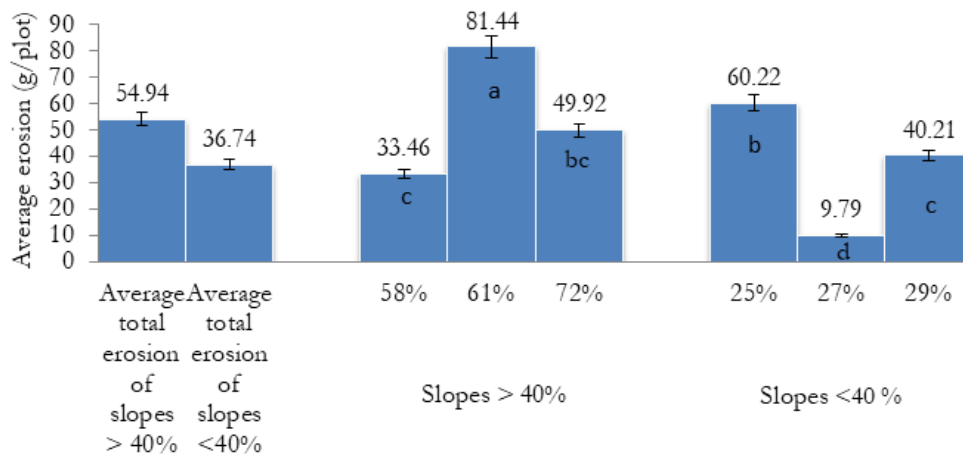


Figure 4. Graph of average erosion and Duncan test on slopes >40% and <40%

72% and 58%. Likewise at the slope of 29% the erosion produced was not significantly different from the slope of 58%.

To find out whether the level of erosion that occurs on slopes > 40 and <40% is different or not, a 2-difference test is used (Independent Samples T). Figure 4 shows the total average value of slope erosion > 40% and <40% of 54.09 g/plot and 36.74 g/plot. The average two different test results (Independent Samples T) the calculated T value = 2.500 is greater than T table that is 1.969 at a significant test level of 0.025 (2-tailed test), then H0 is rejected. At the 95% confidence interval, there was a difference in the average erosion on the slopes of >40% and <40%.

**B. Discussion**

1. Relationship between rainfall intensity and erosion

Some factors that influence the rate of erosion are rainfall pattern, slope, soil type, topography, crop system and management practices (USLE, 2012). Rain intensity has a significant effect on the test level of 5%. The effect is positive, i.e. the higher the rainfall intensity, the higher the erosion (see figure 1). This is in line with the opinion of (Cao et al., 2015) that rainfall intensity positively influences erosion. It's just that the relationship between rainfall intensity and erosion is not strong due

to the influence of the dominant pine canopy.

Dense canopy closure will eliminate the effect of rainfall intensity on erosion (E1-Hassanin et al.,1993); (Ispriyanto et al., 2001). Pine headers can reduce the raindrops so that the kinetic energy of the rainwater will be reduced before it reaches the ground surface. When it reaches the ground, it is also blocked by a thick layer of pine litter. When the rain water has reached the soil's surface, the ability to destroy soil particles is getting smaller and even lost. Layered canopy and thicker litter can protect against the effects of rainfall against erosion (Valeria A et al., 2018).

2. Relationship of slopes to erosion

The slope affects the rate of erosion through the amount of runoff (Nanko, 2006). The steepness of slope affects the magnitude flow coefficient, sediment carrying capacity and displacement of soil particles by rainwater. The steeper the slope greater the rate and amount of runoff, greater the sediment flow (Aburto F et al., 2021). Slopes are linearly related to erosion (Zhang et al., 2018). Slope has a positive correlation with erosion. In contrast to this study, the slope does not significantly contribute to the effect of intensity and cover on erosion. Plot 1 on slopes > 40%, slope of 58% produces erosion of 33.46 g/plot or equivalent to 0.004 tons/ha. This is smaller



than in a four-slope plot <40% slope 25% with an average erosion value of 60.22 g/plot 0.007 tons/ha. This happened because of the influence of dominant vegetation.

The thickness of litter in the pine can inhibit sediment of movement so that it affects the amount of loss of soil particles (Li Xiang et al., 2014). The thickness of pine litter in this study was between 1.6 and 2.6 cm. Pine litter is very instrumental in controlling the rate or speed of runoff water. Pine litter is like a filter that will inhibit sediment transport by runoff water. The flowing water will form a zig-zag, each time it passes through the composition or pile of litter in the form of twigs, leaves that are piled thick, the speed will decrease. Before runoff water reaches the foot of the slope, the concentration of sediment will be smaller. High biomass can provide a protective effect from soil erosion (Valeria A et al., 2018). Slopes do not affect the amount of erosion if the closure is tight or more dominant. Therefore forest stands are very important in controlling erosion (Wang S et al., 2020).

### 3. Effect of pine closure on erosion

There is a significant effect of closure on erosion. There is a significant influence on the test level of 5%, with a negative regression coefficient indicating that closure can reduce erosion. If the percentage of closure is high it will, produce small erosion even on high slopes. This is evidenced at the slope of 58%, significantly different compared to the slope of 25%. Conversely, if the percentage cover is small, it will produce large erosion even on low slopes. This can be proven at a slope of 25% not significantly different from 72%. Likewise, the slope of 29% is not significantly different from 58% and 72%. Therefore the higher the percentage of pine canopy cover, the smaller the erosion so that it can be explained that erosion is significantly correlated with closure (Suryatmojo et al., 2014); (E1-Hassanin et al., 1993).

A thick pine canopy captures more precipitation and breaks it into smaller particles

or particles. Rainwater with a very small particle size, when it falls on the surface of the ground, its kinetic energy becomes weak. Conversely on large rainwater grains have considerable kinetic energy and can destroy soil particles. Every time there is a decrease in forest vegetation cover will have an impact on vulnerability to erosion. Therefore canopy or canopy cover becomes an ecological factor that plays an important role in determining soil erosion (Li Xiang et al., 2014). The existence of forest vegetation as a protector (Cerdà & Doerr, 2008) greatly influences the hydrological cycle (Suryatmojo et al., 2014).

Erosion on a slope of 58% is smaller than a 25% slope due to the multistrata canopy so that the cover becomes denser and thicker. The top canopy layer, *Pinus merkusii*, has a cover percentage of 53.41%. The second is *Alstonia scholaris*, and the third is *Cinnamomum* sp. Sapindaceae's, have total cover percentage was 15.25%. Multilayers vegetation cover can suppress the influence of slope. A dense and thick canopy layer can break down precipitation particles into smaller ones so that they evaporate more easily. This study perception of pines 42.92% of total rainfall 904.50 mm (Rosmaeni et al., 2019). High interception will decrease the amount of rainfall and weaken kinetic energy on the ground surface, so the ability of rainfall particles to destroy is very low and even lost.

Similarly with the research results by Suryatmojo et al. (2014) that suspended sediment in primary natural forests is smaller at 0.15 tons/ha/year compared to a plantation of 10 years old 3.6 tons/ha/year. Although this figure is slightly larger than the figure found in research under the stands of *Pinus merkusii*, both show that good forest vegetation can control erosion even with high slopes (Li Xiang et al., 2014). Ispriyanto et al. (2001) suggested that length and slope factors are not always positively correlated with surface runoff while vegetation cover is dominant. Thus it can be concluded that the vegetation cover factor greatly affects the erosion rate (El Kateb H et

al., 2013).

Vegetation type and level of cover are the most important indicator influencing differences in soil loss (Jianbo L et al., 2018). Empty land without forest cover will lose soil along with the slope and length of the slope. If the length slope increases from 5 to 20 m, soil loss per unit of rainfall increases 2-fold, and sediment concentration increase 5-fold (E1-Hassanin et al., 1993). What we found at a slope of 25% with a canopy cover of 32.95%/plot resulted in an erosion of 60.22 g/plot or equivalent to 0.007 tons/ha, higher than 27% slope only resulted in an erosion of 9.79 g/plot is equivalent to 0.001 tons/ha with a pine canopy cover of 77.27%. Therefore, if the canopy closure is more than 70%, erosion will be close to zero.

A high percentage of canopy cover at a slope of 27% contributes very significantly to slopes below 40%, causing a difference in the average value of erosion with slopes above 40%. This can be shown in the average two difference test (Independent Samples T-Test) with a 95% confidence interval stated that there is a difference in the average erosion on slopes > 40% with slopes < 40%.

Dense and layered vegetation reduces the kinetic energy and speed of rainwater before it reaches the ground surface. Large raindrops are broken up into small particles by the upper layer's canopy, then fall on the second layer until the rain particles get smaller. Before, the surface layer of the soil is still held back by the litter layer. Pine in the shape of needles can break rainwater particles into particles so small that rainwater no longer can sprinkle soil. Its ability to break rainfall particles into granules is very small, causing the rain water to evaporate back into the atmosphere before falling on the surface of the land.

Comparing with the study results of Topic et. al., (2008) found the amount of soil loss in black pine stands (*Pinus nigra* Arn.) With a layer of natural humus and thick grass, slope 320 (62.49%) of 0.0116 tons/ha. Dark black

pine with complete canopy, no grass, soil loss 0.02 tons/ha. Then in pine aleppo stands (*Pinus halepensis* Mill.) Preserved complete crown cover at a slope of 200 (36.4%), soil loss of 0.044 tons/ha, whereas in pine aleppo stands with 200 (36.4%) soil loss the land is 19.93 t/ha. The result is that soil loss due to erosion in burnt areas with a 20° (36.4%) slope is 463 times higher than under the canopy of pine aleppo preserved at a slope of 26°. In general, it can be said that pine stands are effective in controlling erosion.

#### IV. CONCLUSION

Erosion rates on slopes of >40% and <40% are significantly affected by rainfall intensity and closure. Erosions on the slope class of >40% and < 40% area significantly related to the intensity of rain and cover, where the larger slope class has smaller erosion due to closure effect.

The results of this study will have implications for a review of the determination of protected forest areas with a slope of 40%. This number limit is not an absolute number. The results show that erosion occurred less even on slopes >40%, due to the effect of vegetation cover. Based on these results, the delimitation of protected forest on slopes starting at 40% can be reviewed, considering many forest lands with a slope of 40% have been encroached and converted into other uses. Regarding the slope percentage, further research is needed on various species of forest vegetation.

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